3. WFC3 Science Overview

3.1 Instrument Description and Unique Scientific Capabilities

WFC3 will both physically and functionally replace the current Wide Field and Planetary Camera 2 (WFPC2) in the radial instrument bay of HST. WFPC2 is a wide-field, UV-visible imaging camera. Installed in HST in 1993, WFPC2 covers the wavelength range 1200-10500 Å. The initial motivation for WFC3 was to provide backup imaging capability for HST in the period beginning with the fourth servicing mission until the HST end of the mission (i.e. nominally the period 2003-2010). However, the initial instrument concept evolved into the present design of WFC3, which, beyond its backup role, offers new scientific capabilities in both the near-ultraviolet and near-infrared spectral domains (see Figure 1.) WFC3 takes advantage of improvements in detector technology, special optical coatings, thermo-electric cooling techniques, and filter selection to achieve new and unique science capabilities.

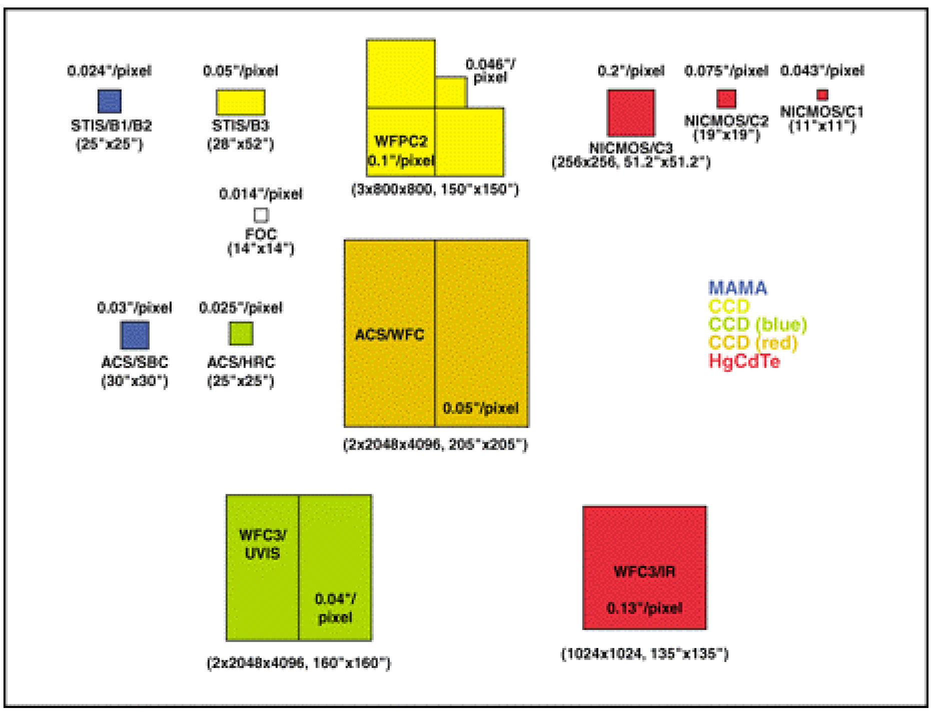

Figure 1. Comparison of the field of view of HST imaging instruments. WFC3 offers a UV-visible field of view comparable to that of ACS/WFC and WFPC2, but with enhanced UV sensitivity, and a near-infrared field of view seven times larger than NICMOS/Camera 3 with better spatial sampling.

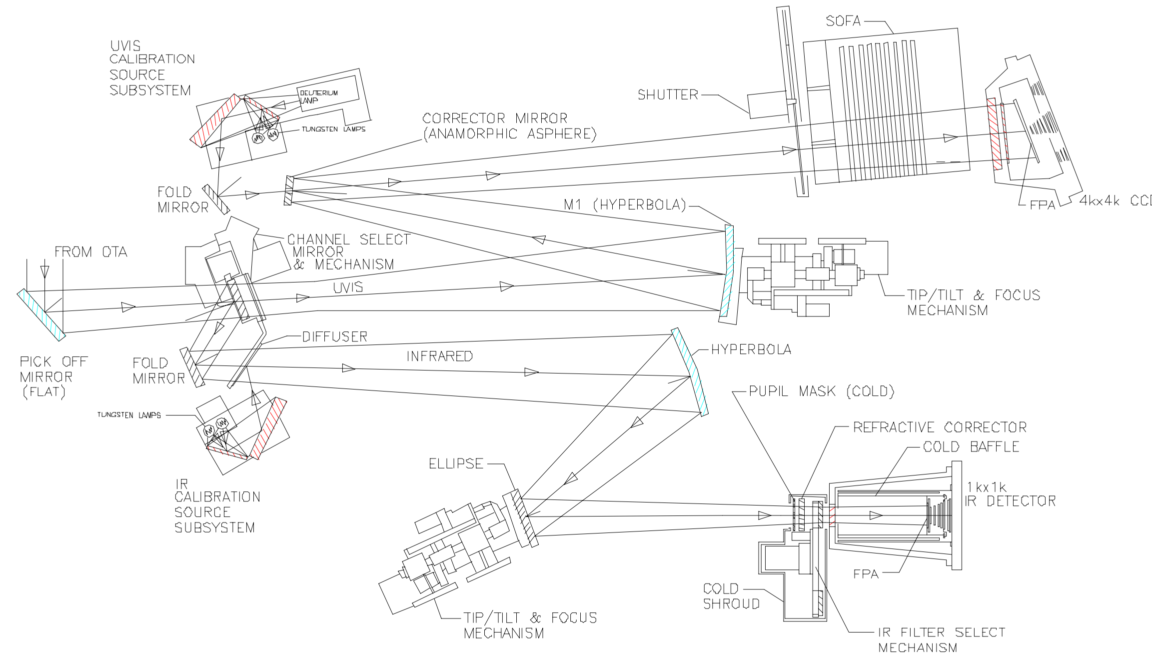

Figure 2. Schematic layout of the two-channel WFC3 instrument.

The instrument consists of two channels: the ultraviolet-visible WFC3/UVIS channel and the near-infrared WFC3/IR channel. Figure 2 provides a conceptual view of the WFC3 instrument. The pickoff mirror is a fixed element capturing light from the center of the HST focal plane and directing it into WFC3. The channel select mechanism is configured to direct light into either the UVIS channel or the IR channel. Each channel contains optics that provide correction for the HST Optical Telescope Assembly (OTA) spherical aberration, bring WFC3 to a common focus with the other HST instruments with a focus and alignment mechanism, and provide the required focal ratio at the detectors. The UVIS and IR filter elements are contained in selectable mechanisms. The design of the UVIS channel is based on elements from the ACS/WFC, with a 4096x4096 Charge Coupled Device (CCD) array covering a 160x160 arcsec field of view (slightly smaller than ACS/WFC and dictated by the size of the pickoff mirror). Since the UVIS channel is optimized in the UV-blue end of the spectrum, it will utilize aluminum mirrors with magnesium fluoride (MgF2) overcoats. Like WFPC2, it has a complement of 48 filters (see Figure 3 and Table 3 in Appendix 9), while ACS/WFC has 23, and STIS only 10. The WFC3 IR channel will house a 1024x1024 Mercury-Cadmium-Telluride (HgCdTe) detector array and has a FOV of 135x135 arcsec. Its optics – other than the Pick-Off Mirror (POM) - will utilize silver mirrors. To minimize internal background flux incident upon the HgCdTe detector, the detector and its surroundings (including the IR filter elements and a "cold stop") will be contained in a cold enclosure. The IR channel accommodates 14 filters (see Figure 3 and Table 4 in Appendix 9). Both the UVIS and the IR channel include dispersive elements (prisms and grisms) for slitless spectroscopy.

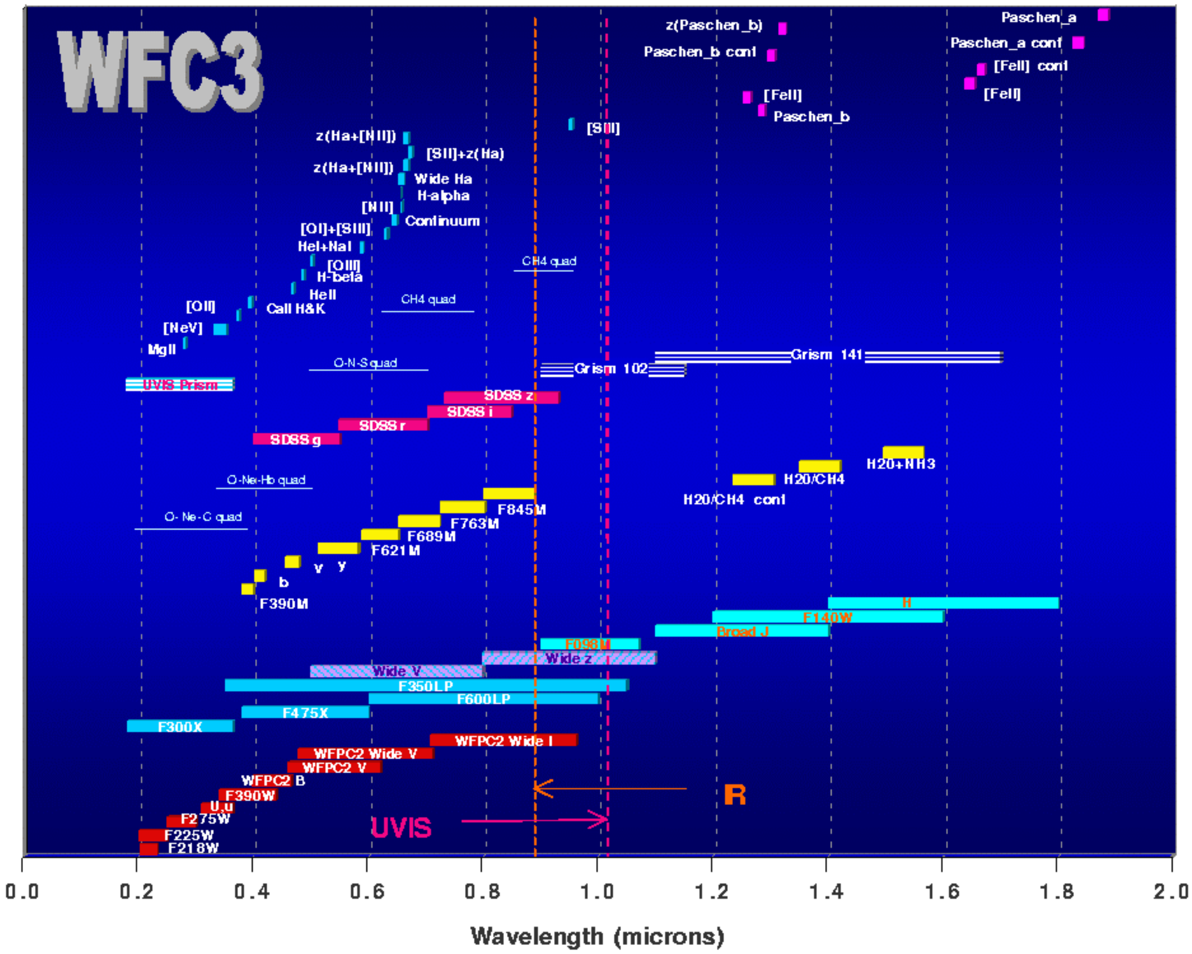

Figure 3: A schematic representation of the WFC3 filter set. The dashed vertical line marked "UVIS" indicates the UVIS channel long-wavelength sensitivity limit. The dashed vertical line marked "IR" indicates the IR channel short-wavelength sensitivity limit.

To compare the performance of HST cameras (apart from angular resolution), a useful index originally introduced by the ACS IDT is the "discovery efficiency," which is defined as the field of view multiplied by the throughput. In Tables 1 and 2 we tabulate the main characteristics and the predicted discovery efficiency of WFC3 compared to other HST instruments.

By using large-format CCD's, both WFC3/UVIS and ACS/WFC produce wide fields with spatial sampling of 0.040 and 0.050 arcsec respectively. These pixel sizes are comparable to that of the WFPC2 Planetary Camera (PC) channel (0.046 arcsec per pixel). However, WFC3 covers 20 times more field area than does WFPC2/PC and 25% more than WFPC2/WF. The WFC3/UVIS design offers a combination of excellent near-UV response and a large field of view (160 arcsec), giving it a discovery efficiency 12 times higher than any prior HST instrument at 3000 Å and 30 times higher than ACS/HRC. This effectively opens up for HST investigation a large new discovery space in the near-UV region.

Table 1: Characteristics of selected HST Imaging Instruments

Instrument	**Wavelength Range (Å)**	**Pixel Size (arcsec)**	**FOV ($arcsec^2$)**
WFPC2/PC	1200-10500	0.046	35 x 35
WFPC2/WF	1200-10500	0.100	3x 75 x 75
ACS/HRC	2000-10500	0.026	26 x 26
ACS/WFC	3500-10500	0.050	205 x 205
STIS/CCD	2000-10500	0.050	51 x 51
NICMOS/CAM2	8000-25000	0.076	19 x 19
NICMOS/CAM3	8000-25000	0.200	51 x 51
WFC3/UVIS	**2000-10500**	**0.040**	**160 x 160**
WFC3/IR	**8000-17000+**	**0.130**	**135 x 135**

Both the Wide Field and Planetary Camera 1 (WF/PC) and WFPC2 had relatively poor response at wavelengths below 3500 Å. Below 2500 Å, the low UV response exacerbated the problem of red leaks (i.e. unwanted long-wavelength photons) in the UV filters. STIS has much improved UV response, good resolution, and much reduced red-leak problem thanks to its Multi-Anode Microchannel Array (MAMA) detectors, but its imaging fields of view are very small (25 arcsec) and are not well matched to large, extended targets such as globular clusters, nearby galaxies, or distant clusters of galaxies. ACS/HRC (using a CCD) and ACS/SBC (using a MAMA detector) offer good response, but again over only small fields (26 arcsec and 30 arcsec, respectively). ACS/WFC has a large field of view but no sensitivity below 3500 Å (see Figure 4.)

WFC3 achieves its good near-UV performance by using aluminum mirrors coated with MgF2 and special blue-optimized antireflection coatings on its CCD detectors. HST is the only NASA-approved large-aperture mission with good UV performance. While NGST will provide higher sensitivity than any HST camera for wavelengths longwards of 6000 Å, its performance below 6000 Å is still not well defined and it is very likely that it will not perform at all shortwards of 4000 Å. In order to balance UV and IR capabilities it is important to have the best UV performance that can be provided for a reasonable cost.

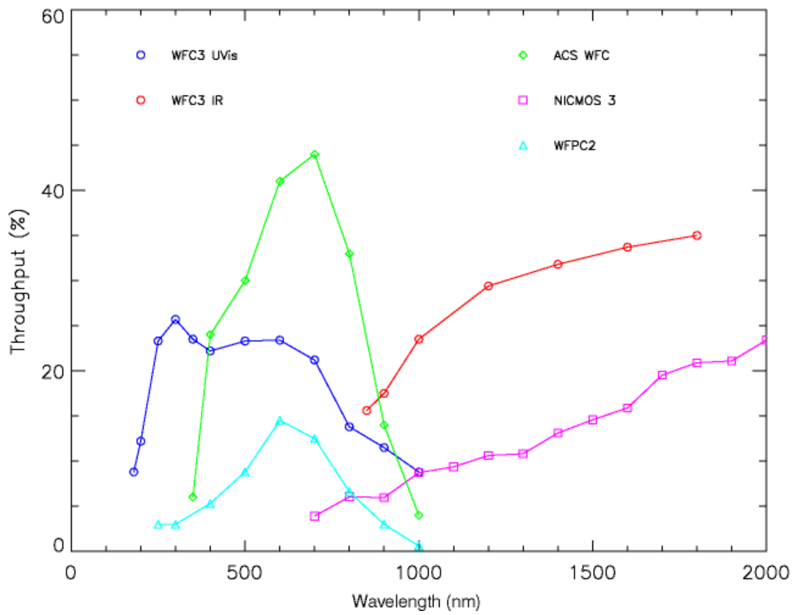

Figure 4. Comparison of the throughput of various HST imaging instruments. WFC3 has the highest throughput of all wide-field imagers both in the UV and in the near-IR.

WFC3's infrared channel will provide an important bridge spanning NICMOS and NGST. This can be achieved because WFC3/IR does not rely on expendable cryogens and thus is able to operate until the end of the HST mission. WFC3/IR will also become a workhorse for identifying objects of scientific interest for further study with NGST, SIRTF, and the large ground-based telescopes. Furthermore, WFC3/IR's good spatial sampling (0.13 arcsec per pixel versus 0.2 arcsec per pixel for NIC3) and larger field of view (135 arcsec vs 51 arcsec for NIC3) will provide an increased discovery efficiency of a factor of 15 in the 9000-17000 Å wavelength region compared to NICMOS (with the NICMOS Cooling System - NCS.)

Table 2 : Discovery efficiency of selected HST imaging. The 3000 and 6000 Å performance is normalized to that of WFPC2/PC, that at 16000 Å to NICMOS/Camera 2. The values for WFC3 are based on the baseline performance. Achieving the goal performance for WFC3 would double its discovery efficiency.

Instrument	**Discovery Efficiency**		
	@ 3000 Å	**@ 6000 Å**	**@ 16000 Å**
WFPC2/PC	1	1	N/A
WFPC2/WF	14	14	N/A
ACS/HRC	5.5	1.0	N/A
ACS/WFC	N/A	110	N/A
NICMOS/CAM2	N/A	N/A	1
NICMOS/CAM3	N/A	N/A	7.2
WFC3/UVIS	**180**	**36**	**N/A**
WFC3/IR	**N/A**	**N/A**	**105**

3.2 General WFC3 Scientific Priorities

Scientific programs for WFC3 naturally fall into two main categories:

(1) Extensions or continuations of imaging programs developed for WFPC2, ACS/WFC, ACS/HRC, and NICMOS;

and

(2) Programs which make use of WFC3's unique capabilities in the UV/IR or are particularly timely for the period 2004-2010. Examples of the latter are programs in support of and as follow-up to other major NASA and ground-based projects, including GALEX, SOFIA, SIRTF, 2MASS, the Sloan Digital Sky Survey (SDSS), and NGST.

Our discussion will focus primarily on scientific programs in the second category. Below we discuss the general potential of WFC3 imaging in the UVIS and IR channels separately, and then as a panchromatic camera covering the largest wavelength span of any HST instrument. In each case we will give a general overview of the capabilities and discuss in detail only a few selected programs aimed at illustrating the scientific potential of the instrument.